

A Historiography of Human-Computer Interaction

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Abstract—This essay examines the state of the history of human-computer interaction (HCI) from multiple fields of study. In many ways, there is a lack of consensus about what we mean by not only HCI but also computer interfaces. I find that the different definitions and approaches found primarily in history and media studies offer many different avenues for scholars to continue exploring how humans and computers relate to each other. A theoretical background on the topic is provided and then historical case studies concerning both computer interfaces and the embodied use of computers are discussed to understand what conversations are held in common and what areas are still left to be explored.

■ **HUMAN-COMPUTER INTERACTION** (HCI)—our relationship with computers at the moment that we operate them using different kinds of input and output and different parts of our bodies—helps us to understand the effects that humans and computers have on each other and how to improve our experience of using computers. It is a subject that we spend significant time on, in all our forms of computer use, even if not consciously aware of its details and intricacies. Yet,

HCI is also nebulous and hard to define firmly. There are two difficulties in assembling any kind of canonical list of works on the history of HCI. First, what became immediately obvious when trying to compile this historiography is that most scholars who write on the subject do not use the phrase “human-computer interaction.” Instead, they talk about computer interfaces, input–output devices, human senses and technology, or the embodied use of computers. Overarching phrases, many of which are particular to specific historical contexts, sit alongside HCI, such as the human–machine interface, the user interface, human-factors design, and man–computer symbiosis. This plethora of broad phrases of course

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leads right to the second difficulty: What marks the limit of “interaction?” That is, when discussing the history of computer technology, what does not count as HCI?

I answer this question by dividing this historiography into two, sometimes overlapping, areas of HCI literature: computers/interfaces and humans/bodies. I find that scholars tend to explicitly or implicitly focus on one of these sides more than the other, but that both concern the meeting point where humans and computers interact. Interfaces, however, further lack an agreed-upon definition. For some scholars, the interface is software on a screen—what the computer displays that a person interacts with. For others, the interface is the entire system of human-computer interaction; it is the process of merging, the coming together of, human and computer into a relationship. The human, then, is as much a part of the interface as the software and the input and output. For yet others still, the interface is a metaphor that takes varying forms, primarily of desktops or doors. This multiplicity of understandings of interface complicate a discussion of HCI that I have approached by letting scholars speak for their own view of what interfaces are while attempting to find commonality between them.¹

The first part of the history of HCI to be discussed then will be the history of interfaces that humans interact with. Most scholarly works that consider HCI are focused on computer interfaces, often using the interface as a stand-in for the place where human and computer meet and interact. To get at the shape of the computer interface in the history of computing, I examine its place in overarching histories of computer technology, then move into the major milestones in HCI development from the perspective of historical works, before concluding with works that cover more specific topics related to interfaces. The final, much smaller, part of this historiography will involve works that consider the embodied use of computers, primarily in terms of the senses.

I argue that there are two major themes running through the history of HCI: the tension between augmentation and user-friendliness in how the computer and the user communicate with each other and the trend toward increasingly

invisible interfaces over time. For the most part, the development of computer interfaces has moved from one theme to the other, from dreams of human augmentation to a goal and reality of user friendliness, to predictions of the future of invisibility and ubiquitous computer technologies. In terms of what such future interfaces might consist of and a critical understanding of both them and role of people in operating them, much is unsettled.

This historiography is not limited to works from the history of technology. In addition to history, much writing on HCI comes out of science and technology studies, media studies and, within that, media archeology. Unsurprisingly, these fields are frequently not in direct communication with each other. To the extent that there are almost independent and parallel sets of citations established within HCI literature. However, there are a number of theorists that at least somewhat cut across the disciplines: in particular, Marshall McLuhan, Friedrich Kittler, Sherry Turkle, and Lucy Suchman. These theorists set the stage for the historical works that follow them, establishing how the computer might be thought of in terms of a media technology that potentially offers a radically new form of interaction with humans.

Although writing prior to when many of the HCI technologies discussed here even existed, McLuhan's *Understanding Media: The Extensions of Man* (originally published in 1964) is a natural fit in this historiography; not only were his ideas groundbreaking for media studies, but McLuhan anticipated many of the concerns and issues that would arise with developments in HCI.² This is not surprising considering that many computer developers themselves were also reading McLuhan and were inspired by him. So there is a circularity to how we read him today, as he influenced both the technology and our understanding of it. The main concept taken from McLuhan is his famous “the medium is the message,” explained by him as: “the personal and social consequences of any medium—that is, of any extension of ourselves—result from the new scale that is introduced into our affairs by each extension of ourselves, or by any new technology.”³ The growth of computer technology underlies much of McLuhan's writing, although he only discusses it directly a few times.

The way he talks about electronics and information, however, presages the coming of new forms of HCI that scholars would apply his words to:

*'In this electronic age we see ourselves being translated more and more into the form of information, moving toward the technological extension of consciousness . . . By putting our physical bodies inside our extended nervous systems, by means of electronic media, we set up a dynamic by which all previous technologies that are mere extensions of hands and feet and teeth and bodily heat-controls—all such extensions of our bodies, including cities—will be translated into information systems.'*⁴

These concepts would go on to inform theories of computers as technologies of human augmentation, where the use of them could take humans beyond not only physical abilities but also mental. The interface of human and computer can extend beyond the body, although, as will be discussed, without any means to actually leave the body fully behind.

Written more than 20 years later, in the midst of the personal computer revolution, but not translated into English until 1999, Friedrich Kittler's *Gramophone, Film, Typewriter* is more explicitly about the computer, in spite of its concern with three older media technologies.⁵ "Those early and seemingly harmless machines capable of storing and therefore separating sounds, sights, and writing ushered in a technologizing of information that, in retrospect, paved the way for today's self-recursive stream of numbers," Kittler writes.⁶ He builds upon McLuhan, concerned with the changes taking place to media with the rise of computer technology. Kittler looked to the effects computers—and more specifically, the coming of fiber optic data transmission—would have on media: "The general digitization of channels and information erases the differences among individual media."⁷ The computer as universal medium had come to pass, as the technology began to subsume all other media within itself, making its interaction with people one of taking in all forms of media together.

The final two theorists I discuss also both began their work on computers in the 1980s: Sherry Turkle and Lucy Suchman. Turkle's 1984 book, *The Second Self: Computers and the Human*

Spirit, tackles HCI directly, in the form of ethnographic research she conducted on groups of gamers, programmers, personal computer owners, and hackers—both children of various ages and adults.⁸ One of the most important contributions of her work is an awareness of HCI being different for different people.⁹ This is HCI at the most individual level, and by focusing on individuals, Turkle is able to capture some of the complexity of what interacting with computers means for them. Drawing upon McLuhan, she speaks to the power of HCI, for example, when discussing a very young child who was learning simple programming: "She is manipulating—perhaps more problematic, *interacting with*—a complex technological medium. And the degree and intensity of her involvement suggests that (like the children at the video games) it is the medium itself and not the content of a particular program that produces the more powerful effect."¹⁰ The power of the computer, for Turkle, is that "it is a constructive as well as a projective medium."¹¹ It is, from the book's title, a "second self" and also an "object-to-think-with."¹² The computer not only provides an interface through which people can learn about themselves, but it allows them to create anything they can imagine. Such possibilities, and the values that are embedded in building a technology that allows for them, run through this history of HCI.

Written a few years later, Lucy Suchman's *Plans and Situated Actions: The Problem of Human-Machine Communication* takes ideas from Turkle in trying to understand how people are interacting with new computer technologies from cognitive science and anthropology perspectives.¹³ Suchman conducted her study within Xerox's Palo Alto Research Center—one of the major sites for developments in HCI technologies—and explains that "now for the first time the term 'interaction'—in a sense previously reserved for describing a uniquely interpersonal activity—seems appropriately to characterize what goes on between people and certain machines as well. Interaction between people and machines implies mutual intelligibility, or shared understanding."¹⁴ There are three properties of computers that contribute to their ability to be interactive for Suchman: they are reactive, linguistic, and internally opaque. The first two are a part of developments in the

technology itself, in which computers have become real-time and operable using increasingly what she calls a “common language” instead of mechanistic means.¹⁵ The final property makes computers less like other machines, as we cannot see inside them similarly to how we cannot see inside other minds. She explains that “the personification of the machine is reinforced by the ways in which its inner workings are a mystery, and its behavior at times surprises us,” therefore, “we are more likely to view ourselves as engaged in interaction with it than as just performing operations upon it, or using it as a tool to perform operations upon the world.”¹⁶ Suchman then goes on to explore the ways that computers are or are not self-explanatory as intended by their designers, finding overall that, due to limitations in how computers are able to communicate, there is an asymmetry in their interaction with humans.¹⁷ Ultimately, however, she argues that probing the limits of machine capabilities can tell us something about those of humans, as “the attempt to build interactive artifacts, taken seriously, could contribute much to an account of situated human action and shared understanding.”¹⁸ All four theorists together, then, offer a framework within which HCI can be examined: that of a universal medium that interacts with people in highly contextual and individual ways and one that they can relate to as external yet intimately connected to themselves. This gives us a background that scholars studying the history of HCI then built upon in different ways.

HISTORY OF COMPUTING THROUGH THE INTERFACE

Broad overarching histories of computing tend to touch upon HCI to various degrees, largely by discussing some of the core events in the development of HCI. These historical high points will be discussed shortly. At a more theoretical level, however, the most substantive consideration of HCI in comprehensive histories can be found in Paul Ceruzzi’s 2012 condensed volume, *Computing: A Concise History*.¹⁹ Ceruzzi considers HCI, under the guise of the human-machine interface, to be one of the core four themes running through computer history, alongside the digital paradigm (the use of binary to

encode information and control electronic machines), convergence (of different technologies together into new ones), and advancements in solid-state electronics. He describes the theme of HCI as “a broad one: it ranges from philosophical implications about humanity to detailed questions about machine design.”²⁰ For Ceruzzi, how humans interact with computers is at the heart of what studying computers is all about and gets at philosophical questions of the differences between humans and machines.

There are two major popular books that explicitly set out to uncover the history of HCI: Howard Rheingold’s *Tools for Thought: The History and Future of Mind-Expanding Technology* and Stephen Johnson’s *Interface Culture: How New Technology Transforms the Way We Create and Communicate*.²¹ Rheingold’s book, first published in 1985, was the first to chronicle the major developments in HCI and the main developers behind them. While its history reads as overly simplified today, he provides an account of increasing interactivity in computing over time. His history travels from the 19th century with Charles Babbage and Ada Lovelace up until the 1980s and the beginning of the consumer Internet, going through the people he labels (in chronological order) as patriarchs, pioneers, or infonauts.²² Looking forward from the mid-1980s, Rheingold predicted the future of computer technology as moving toward a “new medium for human thought,” “mind-amplifying machines,” and “empowerment.”²³ His view of computer technology was very in line with, in particular, the 1970s developers he discusses, ideas of the computer as the ultimate universal machine and communication medium that held the potential to unlock and augment the human mind through our interaction with it. And though Turkle was writing just before him, these ideas are also in line with the potential she grants the computer to change the human mind, particularly as the technology becomes more ubiquitous.

Published roughly a decade later, Johnson’s *Interface Culture* takes a similar tack through the history of HCI as Rheingold but divided into different aspects of the computer interface with a mix of both well-known and more obscure case studies, including the desktop, windows, links, text or word processing, and intelligent agents. Continuing Rheingold’s view of the computer as

communication medium, and building upon both McLuhan and Turkle, Johnson ultimately argues that “The interface serves as a kind of translator; mediating between two parties, making one sensible to the other. In other words, the relationship governed by the interface is a *semantic* one, characterized by meaning and expression rather than physical force.”²⁴ That is, what makes the computer different from other technologies is that it is “a symbolic system from the ground up” and “more often than not, this representation takes the form of a metaphor.”²⁵ As a machine that must communicate with its users in a language they can understand, the computer interface provides a kind of distancing between the user and machine—a translation of each half of the relationship but also a meeting place for the two of them to communicate. This is similar to Suchman’s discussion of conversation between humans and computers, though for her, it is a form of communication that remains yet asymmetrical.²⁶ Johnson’s hope, at the time, was that the metaphor the computer used to translate to the user would eventually move beyond the familiar desktop one into something that would allow for new forms of interactivity between humans and computers.

Out of both of these works then, there is an emphasis on HCI in the form of the kinds of communication from one to the other, along with the general increase in interactivity over time and perhaps a goal of human augmentation. These themes run through each of the major historical episodes, each of which offers an opportunity to compare interpretations from different scholars on exactly what was happening with HCI at the time and what it means for the history of computer technology. The historical cases presented here do not cover every major development in HCI but are instead those most often touched upon by scholars.²⁷ One complication with this history is that while humans and their bodies have not really changed over the course of computer history, the computer has changed tremendously, making the computer of today something that looks and is used very differently than the computer of the mid-20th century. Dramatic changes in interaction are one of the hallmarks of computer development. Paul Dourish describes the changes that took place over this history as

moving from electrical to symbolic to textual to graphical, in terms of how information is presented to the user and the different cognitive and physical abilities users draw upon to communicate with the computer, a pattern that can be seen within each of these historical cases.²⁸

The first major historical moment occurred during the 1940s and World War II. Ceruzzi discusses the emergence of operations research and its efforts to make new technologies work with their military users; he concludes that computers “are effective when their operation—and programming—is pushed down to the user level, whoever that user may be. And the plasticity of computers, the very quality that sets them apart from other machines, will always mean that their use will never be intuitive or obvious.”²⁹ This gets at one of the major currents running through HCI history, the tension between user-friendliness—being able to pick up a new computer and intuitively figure out how to operate it—and larger aims of human augmentation through computer technology. A related core question concerns who or what should adapt to whom; that is “Do we construct machines that do what is technically feasible and adapt the human to their capabilities, or do we consider what humans cannot do well and try to construct machines that address those deficiencies?”³⁰ Ceruzzi argues that this question, too, was first starting to be worked out during this time, although the implications of it continue until today.

One imagined, interactive technology from this time that scholars regularly examine is Vannevar Bush’s Memex—the hypothetical information manipulation machine he wrote about in his 1945 essay, “As We May Think.”³¹ The Memex was to be a library technology, a machine that people could use to access information (stored on microfilm) and add their own annotations or notes of what they discovered. It was a predecessor to hypertext and the Internet, but in analog form, which provided for a different sense of distancing than later digital computer interfaces. In the book based on his 2015 museum exhibit at the Bard Graduate Center, called the *Interface Experience*, Kimon Keramidas argues that “Because Bush was working in an analog world, these designs have a physical approachability that is harder to find in contemporary

computers, whose components have been maximized for size and efficiency by decades of miniaturization.”³² This is the opposite of an invisible interface; it is one literally at the user’s fingertips, in front of them, in a way that cannot fade into the background, as the technology being used was also the furniture it rested within, with its microfilm whirling it brought forth what the user requested. “As a result, there is a more direct connection between the physical design of the Memex’s interface (a term that Bush does not explicitly use) and the perceived improvements in information access experienced by the user.” These perceived improvements were its potential to augment human intellect, in this case, by enhancing our memory and ability to navigate large amounts of information.

Beginning at the same time as these initial questions of HCI, the field of cybernetics would take them up in a slightly different direction. While about the interaction of humans and machines, cybernetics was more concerned with systems comprised of human and machine components or models of such, rather than the individual human using a machine. It was about understanding the world as human-machine systems, where we could consider HCI to be about the moment where a human sits down and interacts with a machine. One of the first to examine the history of cybernetics and its relationship with HCI was Paul Edwards’ 1996 book, *The Closed World: Computers and the Politics of Discourse in Cold War America*.³³ He discusses the role of human-machine integration in cybernetic projects during the Cold War, defining this form of HCI as “building weapons, systems, and strategies whose human and machine components could function as a seamless web, even on the global scales and in the vastly compressed time frames of superpower nuclear war.”³⁴ Significantly, by having this “seamless web” as a goal, the humans in the systems become changed, made into components of the system alongside machines, instead of individual users:³⁵ “Effective human-machine integration required that people and machines be comprehended in similar terms, so that human-machine systems could be engineered to maximize the performance of both kinds of components.”³⁶ Edwards explains how fitting humans into systems became a problem of psychology, with an understanding of that

relationship that he takes from Turkle of the computer as a “second self,”³⁷ within the emergence of cognitive science as a field. New possibilities for HCI arose within “cyborg discourse,” “concerned with the psychological and cultural changes in self-imagining brought on by the computer metaphor.”³⁸ There is a merging of human and computer here, into systems but also into cyborgs, altering both as they adapt to and are understood through each other.

Moving into the 1960s and 1970s, a technological shift took place in how commercial and educational computers were used: the movement from batch processing to time sharing in mainframes. This change involved an entirely new form of HCI, from the separation of labor between programmers designing and writing their programs and operators feeding the punchcards into the computer to individual users sharing one computer at more or less the same time at separate terminals, along with new possibilities for computer-mediated communication of human-to-human via the terminals. This also marked a change in HCI that prioritized the users’ time more, instead of just the computer’s, and brought interaction with computers into the hands of students at schools across the country.³⁹ Edwards describes some of the problems with HCI during the batch processing era, particularly involving the wait for the computer to work through batches while trying to do debugging.⁴⁰ This was a form of HCI that was fundamentally impersonal; time-sharing would then present a new practice of interaction with mainframe computers, where every user is treated by the computer as though they are, if operating optimally, the only one present. Edwards explains the significance of this as that “it would permit individual users to operate the computer ‘interactively’—privately, personally engaged with the machine, without the need for queues and delays between program runs. This, in turn would create the possibilities of on-line debugging (fixing programs while they were running, with the effects of each change instantly visible to the operator), use of graphic displays rather than paper output, and a myriad of other ‘interactive’ features.”⁴¹ These new ideas of interaction were one of the core takeaways of time-sharing, demonstrating possibilities for HCI that would influence developments during the following decades.

Douglas Engelbart's oN-Line System, mouse, and the "Mother of all demos" are perhaps the single most well-covered moment in the history of HCI. The most in-depth and rich in primary sources is Theirry Bardini's book, *Bootstrapping: Douglas Engelbart, Coevolution, and the Origins of Personal Computing*.⁴² Working within history and science and technology studies, Bardini places Engelbart at the start of ideas of computer interfaces that would later result in the graphical user interface (GUI) of the Alto and become entrenched in the personal computer with the Macintosh. People are at the heart of Bardini's take on Engelbart, but it is a view of people coming out of cybernetics and systems theory, as well as from the ideas behind Bush's Memex: "Engelbart and his associates conceived of the personal interface as a hybrid entity derived from both the human and nonhuman participants. That is, it was understood to operate by means of representations, symbolic and material, derived from both, some appearing electronically via integrated circuits and display screens, some deriving from the physical and mental abilities of the people that the designers of the technology imagined using and benefiting from them."⁴³ Engelbart's vision, as a system designer using his own machine, would play a particular role in how he pictured future users interacting with computers, involving his positive-feedback influenced bootstrapping: humans and computers coevolving as they learned how to communicate with each other in an "iterative and coadaptive learning experience."⁴⁴ This coevolution would take place through communication between human and computer, similar to Suchman's take on HCI.

Fred Turner echoes this relationship between cybernetics, the Memex, and Engelbart's vision for computer technology, in his book, *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism*.⁴⁵ Turner argues that "Engelbart saw the individual and the computer, like the group and the computer system, as complementary elements in a larger information system—a system that would use cybernetic processes of communication and control to facilitate not only better office communication, but even the evolution of human beings."⁴⁶ Keramidas views Engelbart's interface

similarly but takes the idea even more abstract: "Engelbart's understanding of the 'man-machine interface' was that it was a boundary or coupling across which energy flowed when human actions and artifact actions were exchanged. He believed the interface to be a border condition that occurred when the human interacted with the machine, not something that consisted of the user and/or material artifacts of the computer."⁴⁷ These visions of the interface as the entire system of HCI or the flows of information between different parts offer scholars a useful tool, one that does more than just reduce the interface to software but forces a consideration of the role of human bodies in this relationship.

Engelbart's interface, on the computer side, consisted of three input devices (keyboard, mouse, and chord keyset) and graphical output on a computer screen; the interface was the place where the user met these technologies. What is striking about these devices is the place of the body in their operation, as these devices were intended to fit humans ergonomically and be easy to use. Engelbart thought of the computer as a prosthesis for the human mind and his input devices as prostheses for the body.⁴⁸ Bardini explains, however, that Engelbart's grand vision of bootstrapping would ultimately fail, as instead "user-friendliness, not coevolutionary learning, became the norm in the design of human-computer interfaces."⁴⁹ This is a major tension in computer interface development, concerning what aspects of computers are easy to pick up and what is the ultimate intended goal for the user from the designer. There are clashes between augmentation—computers that might be difficult to initially learn such that they would push the user to evolve alongside the computer—versus user-friendliness—computers that would be intuitive to pick up and use by anyone regardless of their familiarity. Bardini suggests a future interface that lies in a middle ground, such that with the right interface technologies, Engelbart's vision of the user can match what users themselves want to do, once they are able to do so.⁵⁰

Johnson adds another dimension to Engelbart's interface vision, arguing that the mixture of direct manipulation and graphical interface brought in a new distance between the user and computer,

similar to Keramidas's take on Bush's Memex, however, "the tactile immediacy of the illusion made it seem as though the information was now closer at hand, rather than farther away."⁵¹ Part of this kind of relationship between human and computer was a reconceptualization of the interface as place, which Johnson sees similarly to Bardini: "For the first time, a machine was imagined not as an attachment to our bodies, but as an environment, a space to be explored."⁵² The computer might now promise a way to move beyond the body, into a new, ill-defined, and nebulous space. However, the degree to which this was possible will be explored later.

Another historical moment that is often mentioned in histories of HCI concerns the developments at Xerox PARC in the 1970s and early 1980s. Almost every work on HCI at least mentions either Alan Kay's interest in portable, networked computing and children's education or the creation of the Alto and its graphical interface features. The most complete history of PARC is Michael Hiltzik's popular account, *Dealers of Lightning: Xerox PARC and the Dawn of the Computer Age*.⁵³ At the core of the innovations to come out of PARC were ideas of "personal" computers, which operated not only in real-time but truly one-on-one with humans, allowing for the depth of relationships between humans and computers that Turkle would eventually study. Hiltzik explains that PARC researchers recognized that time-sharing was not good enough in terms of the form of HCI it allowed. To really improve meaningfully would require three things: "placing computing power in individual hands, delivering information directly to the eyeball via a high-performance display, and linking the computers together on a high-speed network."⁵⁴ The Alto would be the result of attempting to achieve this new kind of HCI. Dourish, writing on the history of HCI while working at PARC, explains the importance of space, in a slightly different way than with Engelbart's system, in the GUI that was created with the Alto: "information is spread out over a larger screen area, so that the locus of action and attention can move around the screen from place to place or can even be in multiple places simultaneously (e.g., in different windows). The task of managing information becomes one of managing space."⁵⁵ For Dourish, this marked a new form of embodied interaction with the

computer, involving cognitive abilities such as "peripheral attention," "pattern recognition and spatial reasoning," "information density," and "visual metaphors" that previously had not been utilized when people interacted with computers.

Kay's role in HCI history during his time at PARC is particularly striking, as he was directly influenced by McLuhan's ideas, in similar ways that scholars studying this history have been. If the medium was the message, Kay believed that a computer could be the universal medium, subsuming all others currently existing and still to come within it.⁵⁶ But it was the interface through which a user interacted with this medium. Kay was interested in interfaces as being designed as the "user illusion,"⁵⁷ drawing upon notions of theater and magic behind what is actually happening within the computer versus what is being presented to the user, bringing in distancing between what the user sees and what the computer does.

Bringing the history of HCI more current takes us to the role of digital media and the Internet, involving how people interact with networked computers, with each other through their computers, with portable devices, and with media. Johnson argued of the late 1990s when he was writing that: "we live in a society that is increasingly shaped by events in cyberspace, and yet cyberspace remains, for all practical purposes, invisible, outside our perceptual grasp."⁵⁸ To understand a space as indefinite—or even virtual—as the Internet, the interface was his answer. He also saw a change occurring with the rise of intelligent agents and developments in artificial intelligence, where these programs were becoming "the new interface paradigm." This required a rethinking of the metaphor of the interface: from place or architecture to something livelier, "the computer as personality."⁵⁹ This goes beyond even Turkle's argument for the computer as a place to express or construct one's personality, to the possibility of the computer taking on its own personality, independent of but interacting with the user. Megan Ankerson also sees power in the interaction with computers through the Internet, explaining how the early World Wide Web marked "a new imagined space, a mediated realm that, according to accounts by early web users, felt new, different, and strange

and seemed to hold the potential to upend deep-rooted hierarchies.⁶⁰ Much of HCI history has been future-oriented, especially so regarding interaction with the Internet. Allowing humans to access the hazy realm of cyberspace introduces potentials for bringing the human mind into contact with other minds within digital spaces, which engenders a form of HCI that is increasingly about human-human communication through human-computer interfaces.

To conclude this history of HCI development, I would like to touch upon the intersection of HCI scholarship with HCI development, in the form of social computing. Dourish explains that social computing involves the “application of sociological understanding to the design of interactive systems.”⁶¹ Suchman’s work is perhaps the most well-known example of this meeting of fields, during her time as an anthropologist within Xerox PARC. In a more recent article, she argues for the blurring of design and use, forcing an awareness of a more coconstructive relationship between system designers and users (where each takes on actions of the other).⁶² This suggests a complication to the human-computer relationship in HCI, as never being a one-way street from designer’s intentions to user’s activities, but, as Dourish explains: “Human-computer interaction can be thought of as a form of mediated communication between the end user and the system designer, who must structure the system so that it can be understood by the user, and so that the user can be led through a sequence of actions to achieve some end result.”⁶³ According to these scholars, the future of HCI lies in embracing a more complex understanding of how and why users do what they do, allowing for the possibility of the kinds of relationships based on augmentation that developers throughout this history have called for.

CASE STUDIES IN COMPUTERS/INTERFACES

There are a number of works on interfaces, primarily from media studies, that do not fit neatly into the history of major events in HCI. These works are responding to Kittler in various ways, building upon and pushing back against him, particularly regarding the power that he

grants technology and media (“Media determine our situation...”⁶⁴). Lori Emerson’s 2014 book, *Reading Writing Interfaces: From the Digital to the Bookbound*, does the kind of nonlinear history often found within media archeology. Emerson builds upon both McLuhan and Kittler; however, her take on McLuhan is much more in-depth than other HCI works, as she goes far beyond just using *Understanding Media* to try and get at his ideas from throughout his career. Emerson’s look at the practice of writing through the history of interfaces with different kinds of technology involves “opening up how exactly interfaces limit and create certain creative possibilities.”⁶⁵ She takes a multifaceted view of what interfaces are, arguing that an “interface is a technology—whether it is a fascicle, a typewriter, a command line, or a GUI—that mediates between reader and the surface-level, human-authored writing, as well as, in the case of digital devices, the machine-based writing taking place below the gloss of the surface. The interface is, then, a threshold, but in a more complex sense than simply that which opens up from one distinct space to another distinct space.”⁶⁶ As with many of the other scholars here, the interface is much more than the just the computer half of the human-computer relationship; it is a place of access, but that which it is providing access to is more than just another space but to what is being communicated altogether.⁶⁷

Emerson’s main interest is in the way that interfaces have become increasingly not open throughout their development, claiming that “while interface does grant access, it also inevitably acts as a kind of magician’s cape, continually revealing (mediatic layers, bits of information, etc.) through concealing and concealing as it reveals.” She draws upon ideas of concealment to critique the emergence of the so-called “invisible interface” currently popularized by technology developers. In particular, she is interested in the ways that invisible interfaces make it harder for computer users to have the kind of coconstitutive and coadaptive relationship with their machines espoused by earlier developers such as Engelbart and Kay.⁶⁸ She claims that invisible interfaces “share a common goal underlying their designs: to efface the interface altogether and so also to efface our ability to read, let alone write,

the interface, definitively turning us into consumers rather than producers of content.”⁶⁹ This act of concealing the inner workings of the computer from the user takes place under the espousing of a particular form of “user-friendly” as an inherent value of HCI: “one that depends on and then celebrates the device as entirely closed off both to the user and to any understanding of it via a glossy surface—is the only possible version of the user-friendly, one that claims to successfully bridge the gap between human and computer.”⁷⁰ Emerson sees the Apple Macintosh as a turning point in this history, where the interface then became increasingly black-boxed in the name of greater user-friendliness across the personal computer industry.⁷¹ She laments the loss of earlier conceptions of HCI, those that presented “a philosophy of the user-friendly oriented toward the flexible production (rather than the rigid consumption) of knowledge.”⁷² The effects of increasing levels of abstraction between the computer and user, and the different ways that interfaces have always been black-boxed, suggest a ripe area for future HCI scholarship.

Alexander Galloway provides a slightly different take on both Kittler and the idea of invisible interfaces, in his 2012 book, *The Interface Effect*.⁷³ He pushes back against Kittler, particularly his privileging of hardware over software with its focus on objects and artifacts, as well as his remediation argument, where new media subsumes previous media within itself.⁷⁴ When thinking about the computer interface as something like a threshold, similar to windows or doors, Galloway argues that “As technology, the more a dioptric device erases the trace of its own functioning (in actually delivering the thing represented beyond), the more it succeeds in its functional mandate; yet this very achievement undercuts the ultimate goal: the more intuitive a device becomes, the more it risks falling out of media altogether, becoming as naturalized as air or as common as dirt.”⁷⁵ Instead of focusing on the effects of the invisible interface on the user—closing off the device under the guise of user-friendliness—he instead offers a perspective where the interface makes itself meaningless as it becomes truly invisible. However, as with Emerson, he pushes back at the idea that the interface is only a threshold,

that this is actually a misleading idea created by the interface.⁷⁶ There is no truly stepping across the computer interface into what lies beyond; so, thinking of it as a threshold misses out on what is actually happening when people interact with computers. An interface then is actually more like the metaphorical interfaces encountered in the history of its development. As Galloway says “the interface is ultimately something beyond the screen;” that is, “[it] is a general technique of mediation evident at all levels; indeed it facilitates the way of thinking that tends to pitch things in terms of ‘levels’ or ‘layers’ in the first place.”⁷⁷ The interface for him is an allegory for the way we interact with the world; it is all forms of mediation between subject and object.

Moving to a far more specific case, and also taking into account the role of human bodies in interacting with computers, Matthew G. Kirschenbaum’s 2016 book, *Track Changes: A Literary History of Word Processing*, comes at HCI without describing it such.⁷⁸ The entire book, however, is about HCI at the individual level, showing how word processing technologies impacted the work of various well-known authors. The interaction here is the process of writing, and Kirschenbaum describes the role of computers as: “The user sees only distant shadow of [electrical] phenomena, which are recast as phosphorescent flickers on her screen—shapes and letters, still and moving pictures, all of which we recognize and manipulate. The result of all those dense layers of mediation amplifying and echoing one another is an utterly unique experience, one that many of us can still remember from our own first encounter with a word processor.”⁷⁹ He comes at the history of word processing from a media studies perspective, building closely upon Kittler, and telling the kind of reverse chronology found in the other media archeology works discussed here. He brings bodies into the picture in both his consideration of how individual authors interacted with their computers but also in what he considers an interface to be, “by which I mean not only what is literally depicted on a screen (menus, icons, and windows) but also an interface in the fuller sense of a complete, embodied relationship between a writer and his or her writing materials.”⁸⁰ This perspective of the interface as the

entire system of HCI forces an acknowledgment of the role of the human body in ways that other understandings of the interface can leave out.

CASE STUDIES IN HUMANS/BODIES

The computer interface then is a communication medium, a user illusion, a metaphor, symbols, a space, and a mediation; the differences between these mark where bodies come in and the different ways, physically, that humans experience interaction with computers. There is far less historical work on the place of human bodies in the HCI relationship. Of those that have been written, they tend to engage with bodies in two, sometimes overlapping, ways: through the physical, mechanical manipulation of computing devices using parts of the body (typically, the hands) or through interactions with the senses (the most common being sight and touch).

Don Ihde tackles the relationship between bodies and technology in both ways, by examining internet technologies as embodied from a philosophical perspective, in his 2002 book, *Bodies in Technology*.⁸¹ He plays with ideas of virtuality and physicality in cyberspace: “Our ‘reach’ has extended now to global sites through the Internet, our experiences have been transformed, we are able to enter cyberspace through the primitive virtual reality engines of the present, and we are tempted to think we can transcend our bodies by the disembodiments of simulation.”⁸² Ihde classifies two forms that bodies take in their interaction with computer technology. Body one is the body in terms of its physical attributes, such as types of perception and mobility. Body two is the social or cultural body and the significance of the body in those realms.

It is body one that is at the heart of HCI,⁸³ but that interface of body and computer then impacts body two and our cultural understanding of the relationship between bodies and computer technology. Ihde argues that “As the fantasy element of cyberspace is amplified, one can choose to be anything one can imagine. So here the elements of fantasized cultural bodies come into play as a kind of instant machinic theatrical role.”⁸⁴ He gets at some of the ideas of interfaces expressed previously, that is, the promise of human augmentation

and changes to ourselves through our interaction with computers. At its furthest extreme, this becomes a fantasy of disembodiment, where “We can—in technological culture—fantasize ways in which we get beyond our physical limitations or our social problems by means of technologies created in utopian imaginations.”⁸⁵ Ihde does not present a solution to the tension between the reality of bodies in the interface and the dream of leaving that body behind but, for now, forces an acknowledgement of the place of the body in interacting with technology today, talking about technologies such as prostheses that are directly incorporated into the body as being compromises that are useful if not fulfilling the dream of becoming more than human through technology.⁸⁶

One topic concerning HCI and bodies, which has been fairly well-covered, is virtual reality (VR). Early in the development of the technology, Rheingold published his oft-cited book, *Virtual Reality*.⁸⁷ Bodies are at the heart of all interaction with VR technology. As Rheingold describes what it was like to use VR in the late 1980s: “My body wasn’t in the computer world I could see around me, but one of my hands had accompanied my point of view onto the vast electronic plain that seemed to surround me, replacing the crowded laboratory I had left behind, where my body groped and probed.”⁸⁸ VR becomes a way to sort of leave the body behind but is also always entirely dependent on the body being present.

In 1999, Ken Hillis approached VR more theoretically in his book, *Digital Sensations: Space, Identity, and Embodiment in Virtual Reality*.⁸⁹ He likewise gets at the disconnect of embodiment and disembodiment that seems rooted in VR technologies, arguing that “as a technology and a social practice, VR exemplifies a Western yearning for transcendence via achieving physical and cultural imaginative remove of the subject’s mind from her or his body,” and “[Virtual Environments] suggest that direct access to knowledge reduced to information is possible by visible means alone, yet human bodies anchor our ability to extend ourselves imaginatively into the world, and to do so in an ethical manner.”⁹⁰ Hillis directly probes at this tension, asking “In VEs, however, are users’ bodies really dispensed with, ‘parked’ somehow, or ‘collapsed?’.”⁹¹ I

would argue that all the authors here make it clear that it is not so; the body always remains.

I have also engaged with the relationship between bodies and computers through the history of interfaces and HCI in my 2015 book, *Making Computers Accessible: Disability Rights and Digital Technology*.⁹² In particular, I examine the gradual shift from text-based (or command-line) interfaces to GUIs with personal computers and the effects this change had on people with different disabilities and, therefore, different ways of doing HCI. I argue that, with the GUI: "This innovation led to, for the most part, personal computers being more user-friendly, but, as with any change in a technology, certain assumptions were built in regarding who would use it and how. People with certain kinds of bodies found GUIs an improvement, while others—particularly those with vision impairments—experienced a new obstacle in interacting with the computer."⁹³ Similar to Emerson's critique of interfaces increasing concealment over time, I see the GUI as creating a situation where "the user is further removed from the computer architecture itself and experiences the computer as something familiar and commonplace."⁹⁴ For some users, with certain disabilities (such as particular learning disabilities), this tradeoff was worth it, as the GUI allowed for easy use of the computer where the text-based interface could be difficult to interact with. However, people with different bodies and different needs encountered the GUI as an, initially at least, insurmountable obstacle. For a number of years, blind people were simply unable to use GUI computers, until screen readers could be made to work with the new kind of interface.⁹⁵ This case forces a consideration of HCI where some people are unable to experience it at all, and all the different values behind interfaces—such as user friendliness or goals of coevolution—become moot because people with certain bodies have not been anticipated as computer users.

Continuing to think about the role of sight in interaction with computers, Nanna Verhoeff considers the relationship between vision and touchscreen mobile interfaces by focusing on both the screen and the body, in her 2012 book, *Mobile Screens: The Visual Regime of Navigation*.⁹⁶ Examining different historical case studies, she highlights the moment of interaction with a screen and the role of the senses of sight and

touch in both creating what appears on the screen, as well as taking in its output, such that "what is shown on the screen has to do with how one interacts with it, that is, we can almost literally see what we are doing."⁹⁷ The use of both sight and touch together, particularly with mobile touchscreens, such as gaming devices, tablets, and smartphones, enables a different kind of place of the body in HCI. As Verhoeff argues, "But if touchscreen shifts the metaphor from eye to touch, from vision to tactility, something else also happens. The idea of the touchscreen signifies a definitive leave taken from the illusion of retinal looking—of looking with the body aloof, uninvolved, and protected from influence."⁹⁸ The entire body becomes a part of the HCI experience, reminiscent of the imagined analog interaction with Bush's Memex. The distancing of the body that was discussed alongside the GUI and the movement toward invisible interfaces is, strikingly, reversed here; by incorporating multiple senses working together to produce input and take in output, the body becomes part of the interface in a way that is almost blended with the computer side of the relationship, as in the idea of Engelbart's interface as energy flowing in the exchange of actions between human and machine. Perhaps invisible interface is not quite the right description of what is happening with the use of these computer technologies, but more a mingled interface, where the human body and the computer hardware/software become inseparable.

The final work on the history of HCI that I would like to discuss is David Parisi's recent book, *Archaeologies of Touch: Interfacing with Haptics from Electricity to Computing*.⁹⁹ Parisi looks at the history of haptic technologies and the role of touch as a sense that developers have both wanted and struggled to incorporate into technologies. He builds upon McLuhan (as well as Rheingold's and Hillis's VR works), with a view of "media as imperfect extensions of the human nervous system, functioning as fragmented, selective, and necessarily imperfect externalizations of the senses," but he argues that touch was treated by McLuhan as only metaphor and lacking the bodily reality of what it means to move one's limbs and touch something.¹⁰⁰ True haptics—being able to replicate

touch with a machine—has been a Holy Grail for technology developers that would “wipe away the old subject of information machines—the one whose bodily and perceptual habits had to acclimate to the interface’s taxing artificiality—and replace it with a new haptic subject, fully embodied through the interface.”¹⁰¹ Yet, as a Holy Grail, the ultimate haptic interface is never quite achieved, particularly for VR technologies. The potential, though, remains for touch to be more: “It is not enough that the addition of haptics transforms media interfacing. It also must transform (to again recall McLuhan) the humans that media interface with and the social and economic practices that arise from the agitations of their newly reconstituted sensing selves.”¹⁰²

This ever unrealized dream of a true haptic interface is then contrasted with the touchscreen interfaces that have become popular today. Parisi sees these as not doing what haptic interfaces have the potential to do, to engage touch in complex ways as the predominant sense for HCI. And yet, there is a seductive appeal of the touchscreen as good enough, bringing touch in but in ways that are not ultimately fulfilling: “The movements of the hands and fingers are acclimated to particular demands of sensitive screens, as a new set of fundamentally haptic bodily habits allows the users to become legible to computing machines,” and “the intuitive ease with which young children manipulate touchscreen images—both as a source of jubilation and of moral panic—seems to confirm advertisers’ claims that touch interfacing circumnavigates the need for cultural training, tapping into an innate, naturalistic storehouse of gestures.”¹⁰³ This marks a form of HCI seemingly opposite of that where the computer is intended to augment human intellect; this is interaction in the most bodily and sensual form but one that promises to open new kinds of doors in what computers can do for us, if only we could ever truly achieve it.

CONCLUSION

In many ways, HCI is a nebulous concept in the history of computing. Because almost every account of computer technology involves interaction between humans and computers in some form, it is hard to pin HCI down as its own thing,

its own analytic category through which to understand the history of computers. Of the works discussed here, however, there are a number of fairly concrete threads running through them. One is an attempt to understand exactly what the computer interface is. Scholars engage with this concept in a number of ways. Many draw upon something similar to Engelbart’s idea, where the interface is something fluid, or even energy, through which interaction between humans and computers takes place. The interface is something akin to an assemblage here—the system of human and computer interacting. This provides for potentially powerful ways to understand the relationship occurring between the different components of the system but runs the risk of eliding the individuality of those components themselves, such as the software, screen, input devices, human senses, and hands. The interface is also a metaphor, but of what is up for debate. More popularly, however, the interface is software and hardware. It is text based or graphical, and involving the use of different kinds of input and output devices. With the definition never locked down, the meaning of the interface must be spelled out in every work.

There have also been enormous changes to interfaces and HCI over computer history. A tension has arisen and become stark at various times between goals of interfaces providing for a user-friendly experience versus wanting computers to offer new ways of learning and even for the augmentation of the human mind. This tension has become particularly striking with the rise of ubiquitous and invisible interfaces, where our interaction with computers becomes something we are potentially not even aware that we are doing.

To foreground the interface then, I argue, is to emphasize the embodiment of interaction with computers. By defining the interface as the system of HCI, then, even with invisible interfaces, the body remains visible, as it provides the means through which we engage input and take in output. In general, much remains to be studied concerning the place of the body in computer history and people’s interaction with technology, such as new kinds of bodily interaction with computers in the form of wearable or embedded digital technologies. One new arena to be explored lies in human-machine integration, research that

centers the human body in trying to extend it with computer technology.¹⁰⁴ Another major understudied area is the field of HCI itself as a subject of scholarly analysis. With few exceptions, there is a lack of sense of HCIs development over time, with its departments, degrees, and positions in industry.¹⁰⁵ Dourish's book and some of Suchman's accounts of her work at PARC provide a look at the relationship between HCI and the social sciences, but there remains more to this history to study. There is also a lack of engagement between history and media studies as the two core fields examining the history of HCI. Each could learn from the other in more deliberate ways, particularly through the sharing of historical context and theoretical approaches. Overall, HCI needs to be drawn out more in histories of computing; it needs to be center-staged as a framework, with different understandings of interfaces and bodies, through which we can examine aspects of computer technology and computer users. In order to get a real sense of the history of HCI, it needs to not be this nebulous concept in the background of all interactions between humans and computers but instead foregrounded as the place where humans and computers communicate and change each other.

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■ REFERENCES/ENDNOTES

1. For more on the slipperiness of the word "interface," see J. Grudin, "Interface: An evolving concept," *Commun. ACM* vol. 36 no. 4, pp. 110–119, Apr. 1993.
2. M. McLuhan, *Understanding Media: The Extensions of Man*. Cambridge MA USA MIT Press, 1994.
3. McLuhan, *Understanding Media* p. 7.
4. McLuhan, *Understanding Media* p. 57.
5. F. A. Kittler, *Gramophone, Film, Typewriter* Stanford CA USA Stanford Univ Press, 1999.
6. Kittler, *Gramophone, Film, Typewriter* p. xi.
7. Kittler, *Gramophone, Film, Typewriter* p. 1.
8. S. Turkle, *The Second Self: Computers and the Human Spirit*. New York NY USA: Simon & Schuster, 1985. While this is the most popular of Turkle's books for scholars working on the history of HCI, her 1997 book, *Life on the Screen*, is also sometimes cited. S. Turkle, *Life on the Screen: Identity in the Age of the Internet*. New York NY USA: Simon & Schuster, 1997.
9. Turkle, *The Second Self* p. 15
10. Turkle, *The Second Self* p. 93
11. Turkle, *The Second Self* p. 108
12. Turkle, *The Second Self* p. 22
13. L. A. Suchman, *Plans and Situated Actions: The Problem of Human-Machine Communication* Cambridge UK: Cambridge Univ Press, 1987
14. Suchman, *Plans and Situated Actions* p. 6
15. Suchman, *Plans and Situated Actions* p. 11.
16. Suchman, *Plans and Situated Actions* p. 16.
17. Suchman, *Plans and Situated Actions* p. 181.
18. Suchman, *Plans and Situated Actions* p. 189.
19. P. E. Ceruzzi, *Computing: A Concise History* Cambridge MA USA MIT Press 2012. Other broad computer histories, such as Ceruzzi's *A History of Modern Computing*, 2nd ed. Cambridge MA USA MIT Press 2003 and M. Campbell-Kelly, W. Aspray, N. Ensmenger, and J. Yost's *Computer: A History of the Information Machine* 3rd edition (Boulder, CO: Westview Press, 2013) touch upon some of the major historical developments of HCI, but do not draw it out as a core theme throughout the books.
20. Ceruzzi, *Computing* p. xv.
21. H. Rheingold, *Tools for Thought: The History and Future of Mind-Expanding Technology* Cambridge MA USA MIT Press, 1985 and S. Johnson, *Interface Culture: How New Technology Transforms the Way We Create and Communicate* New York NY USA HarperCollins, 1997.
22. Rheingold, *Tools for Thought* 15. Rheingold was working primarily from interviews with these developers as sources for his history. There are a number of more direct collections of essays or interviews with computer developers who worked on aspects of HCI, which provide useful resources for scholars. See, in particular, A. Goldberg, Ed., *A History of Personal Workstations* New York NY USA ACM Press, 1988, B. Laurel, Ed., *The Art of Human-Computer Interface Design* Boston MA USA Addison-Wesley, 1990, and B. Moggridge, *Designing Interactions* Cambridge MA USA MIT Press, 2007.

23. Rheingold. *Tools for Thought*. p. 13

24. Johnson. *Interface Culture*. p. 14 Emphasis in original.

25. Johnson. *Interface Culture*. p. 15

26. Suchman. *Plans and Situated Actions*. p. 181.

27. A more detailed technical history of HCI technologies can be found in B. A. Myers. "A brief history of human computer interaction technology." *ACM Interact.* vol. 5, no. 2, pp. 44–54. Mar. 1998

28. P. Dourish. *Where the Action Is: The Foundations of Embodied Interaction*. Cambridge MA USA MIT Press. 2004. p. 5.

29. Ceruzzi. *Computing*. p. 159.

30. Ceruzzi. *Computing*. p. 42.

31. V. Bush. "As we may think." *Atlantic*. Accessed Jul 30. 2020 [Online]. Available: <https://www.theatlantic.com/magazine/archive/1945/07/as-we-may-think/303881/>

32. K. Keramidas. *The Interface Experience: A User's Guide*. New York NY USA: Bard Graduate Center 2015. p. 9.

33. P. N. Edwards. *The Closed World: Computers and the Politics of Discourse in Cold War America*. Cambridge MA USA: MIT Press. 1997.

34. Edwards. *The Closed World*. p. 1.

35. Edwards. *The Closed World*. p. 125

36. Edwards. *The Closed World*. p. 147

37. Edwards. *The Closed World*. p. 19

38. Edwards. *The Closed World*. p. 21.

39. For an in-depth treatment of the historical development of timesharing see J. L. Rankin. *A People's History of Computing in the United States*. Cambridge MA USA: Harvard Univ. Press. 2018.

40. Edwards. *The Closed World*. p. 256

41. Edwards. *The Closed World*. p. 257

42. T. Bardini. *Bootstrapping: Douglas Engelbart, Coevolution, and the Origins of Personal Computing*. Stanford CA USA: Stanford Univ. Press. 2000.

43. Bardini. *Bootstrapping*. p. 2.

44. Bardini. *Bootstrapping*. p. 24.

45. F. Turner. *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism*. Chicago IL USA: Univ. Chicago Press. 2010

46. Turner. *From Counterculture to Cyberculture*. p. 108

47. Keramidas. *The Interface Experience*. p. 11.

48. Bardini. *Bootstrapping*. p. 102.

49. Bardini. *Bootstrapping*. p. 215.

50. Bardini. *Bootstrapping*. p. 227.

51. Johnson. *Interface Culture*. p. 21.

52. Johnson. *Interface Culture*. p. 24

53. M. A. Hiltzik. *Dealers of Lightning: Xerox PARC and the Dawn of the Computer Age*. New York NY USA: HarperCollins. 2000

54. Hiltzik. *Dealers of Lightning*. p. 170.

55. Dourish. *Where the Action Is*. p. 11.

56. L. Emerson. *Reading Writing Interfaces: From the Digital to the Bookbound*. Minneapolis MN USA: Univ. Minnesota Press. 2014. pp. 55–57.

57. Quoted in Johnson. *Interface Culture*. p. 59

58. Johnson. *Interface Culture*. p. 19

59. Johnson. *Interface Culture*. p. 176

60. M. S. Ankerson. *Dot-Com Design: The Rise of a Usable Social Commercial Web*. New York NY USA: NYU Press. 2018. p. 13.

61. Dourish. *Where the Action Is*. p. 55

62. L. Suchman. "Located accountabilities in technology production." *Scandinavian J. Inf. Syst.* vol. 14, no. 2 pp. 91–105. 2002.

63. Dourish. *Where the Action Is*. p. 56

64. Kittler. *Gramophone, Film, Typewriter*. p. xxxix

65. Emerson. *Reading Writing Interfaces*. p. ix.

66. Emerson. *Reading Writing Interfaces*. p. x

67. Emerson. *Reading Writing Interfaces*. p. 132.

68. Emerson. *Reading Writing Interfaces*. pp. 52–54.

69. Emerson. *Reading Writing Interfaces*. p. xvii.

70. Emerson. *Reading Writing Interfaces*. p. xi. Emphasis in original

71. Emerson. *Reading Writing Interfaces*. p. 32

72. Emerson. *Reading Writing Interfaces*. p. 54

73. A. R. Galloway. *The Interface Effect*. New York NY USA: Wiley. 2013.

74. Galloway. *The Interface Effect*. p. 7 and 21.

75. Galloway. *The Interface Effect*. p. 25.

76. Galloway. *The Interface Effect*. p. 53

77. Galloway. *The Interface Effect*. p. 54.

78. M. G. Kirschenbaum. *Track Changes: A Literary History of Word Processing*. Cambridge MA USA: Harvard Univ. Press. 2016.

79. Kirschenbaum. *Track Changes*. p. 5

80. Kirschenbaum. *Track Changes*. p. 13

81. D. Ihde. *Bodies in Technology*. Minneapolis MN USA: Univ. Minnesota Press. 2002

82. Ihde. *Bodies in Technology*. p. xi.

83. Ihde. *Bodies in Technology*. p. 69.

84. Ihde. *Bodies in Technology*. p. 85.

85. Ihde. *Bodies in Technology*. p. xiii.

86. Ihde. *Bodies in Technology*. p. 14.

87. H. Rheingold. *Virtual Reality*. New York NY USA: Simon & Schuster. 1992

88. Rheingold. *Virtual Reality*. pp. 15–16.

89. K. Hillis. *Digital Sensations: Space, Identity, and Embodiment in Virtual Reality*. Minneapolis, MN, USA: Univ. Minnesota Press, 1999.

90. Hillis. *Digital Sensations*. p. xl.

91. Hillis. *Digital Sensations*. p. 166.

92. E. R. Petrick. *Making Computers Accessible: Disability Rights and Digital Technology*. Baltimore, MD, USA: JHU Press, 2015.

93. Petrick. *Making Computers Accessible*. p. 22.

94. Petrick. *Making Computers Accessible*. p. 25.

95. Petrick. *Making Computers Accessible*. p. 27.

96. N. Verhoeff. *Mobile Screens: The Visual Regime of Navigation*. Amsterdam, The Netherlands: Amsterdam Univ. Press, 2012.

97. Verhoeff. *Mobile Screens*. p. 15.

98. Verhoeff. *Mobile Screens*. p. 87.

99. D. Parisi. *Archaeologies of Touch: Interfacing With Haptics from Electricity to Computing*. Minneapolis, MN, USA: Univ. Minnesota Press, 2018.

100. Parisi. *Archaeologies of Touch*. pp. xiv–xv.

101. Parisi. *Archaeologies of Touch*. p. 23.

102. Parisi. *Archaeologies of Touch*. p. 299.

103. Parisi. *Archaeologies of Touch*. pp. 283–284.

104. F. F. Mueller *et al.* “Next steps for human-computer integration.” in *Proc. Conf. Human Factors Comput. Syst.*, 2020, pp. 1–15.

105. Notable exceptions are J. Grudin’s insider history of HCI as a field in J. Grudin. *From Tool to Partner: The Evolution of Human-Computer Interaction*. San Rafael, CA, USA: Morgan & Claypool Publishers, 2017 and J. Grudin. “Three faces of human-computer interaction.” *IEEE Ann. History Comput.*, vol. 27, no. 4, pp. 46–62, Oct 1, 2005.

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